DOCUMENT RESUME

ED 256 570 SE 045 500

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TITLE Philosophical Examination of the Problem of the Unlearning of Incorrect Science Concepts.
PUB DATE Apr 85
NOTE 41p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (58th, French Lick Springs, IN, April 15-18, 1985).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Concept Formation; Concept Teaching; Elementary Secondary Education; Higher Education; Learning Strategies; *Philosophy; Research Methodology; *Science Education; *Science History; *Science Instruction; *Scientific Concepts
IDENTIFIERS *Misconceptions; Science Education Research

ABSTRACT

Speculative philosophical methodology was used to generate ideas about ways science teachers might help students recognize and unlearn erroneous notions about science and replace them with sound new science concepts without lessening students' intellectual self-confidence or alienating their receptivity to further science learning. The research was conducted in four phases: (1) literature review on common misconceptions in science (finding misconceptions related to virtually every science-related field from kindergarten through college); (2) reflective analysis on the nature of the misconceptions identified in the literature; (3) speculative assessment of major studies for insight and ideas regarding alternative ways to approach the problem; and (4) speculative justification of conclusions and suggestions for further research. Based on such findings as the persistence of misconceptions after formal science instruction, a rationale is offered for the systematic inclusion of the history of science in science teaching, specifically the history of the development of those major concepts about which common misconceptions exist today. Such instruction could help students recognize and appreciate the inadequacies of their own incorrect ideas. (A brief explication of the nature and applications of philosophical enquiry is appended.) (JN)

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PHILOSOPHICAL EXAMINATION OF THE PROBLEM OF THE UNLEARNING OF INCORRECT SCIENCE CONCEPTS

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A report of research presented at the 1985 Annual Meeting of the National Association of Research in Science Teaching.

French Lick, Indiana
April, 1985

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PHILOSOPHICAL EXAMINATION OF THE PROBLEM OF THE UNLEARNING OF INCORRECT SCIENCE CONCEPTS

Introduction

Most students, including those at the elementary school level, enter their first formal science study with many intelligently conceived and quite sophisticated concepts of science. Some of these may be compatible with the principles of modern science and some may be incorrect, inadequate, outdated, or otherwise unacceptable in a science oriented culture (Ault, 1984; Clement, 1982; Driver, 1983; Kuethe, 1963). Concepts based on sound science information, of course, constitute a basis for further science education. Alternative conceptual frameworks based on intuitive misperceptions, naive inferences, incorrect logic, and/or misinformation constitute a threat to further science education.

Research from cognitive psychology and science education has indicated that some misconceptions are not displaced by subsequent science instruction (Caramazza, McCloskey, and Green, 1981; Champagne, Klopfer, and Anderson, 1980; Clement, 1982; Driver, 1983; McCloskey and Kohl, 1983). For example, many adults who have studied physics in high school and college continue to hold preconceived intuitive concepts of motion similar to the medieval theory of <u>impetus</u>, which is inconsistent with the principles of Newtonian mechanics (Kuethe, 1963; McCloskey,

1983, 1984). Many students also continue to hold outdated concepts of absolute time (Ault, 1984).

"For the person who holds it, a misperception feels like the truth--he doesn't know that he doesn't know" (Eaton, Anderson, and Smith, 1983, p. 7). Furthermore, when an incorrect scientific notion has supplied a satisfactory explanation of a student's experiences, the correct concept, when encountered in formal science instruction, may be disregarded or "more likely . . . misperceived or distorted by students so as to fit their existing preconceptions" (Clement, 1982, p. 70). Consequently, teachers cannot simply assume that erroneous preconceptions of science will be recognized by students and replaced by correct science information in the course of formal science instruction (DiSessa, 1982; Driver, 1983).

It is clearly in the interest of science education to help students quickly recognize the inadequacy of incorrect perceptions of science they may hold and replace them with concepts that are consistent with modern science. This may not be a simple matter because many persons holding such perceptions are "intelligently wrong" (Ault, 1984, p. 22). Their ideas may be based on purposive observations, careful thought, reasonable interpretations of meaningful experiences, and/or authoritative non-science sources of information. Consequently, it is important that efforts to help students recognize and unlearn inadequate preconceptions not undermine their intellectual self-confidence or

otherwise alienate their receptivity to further science learning.

Considering the reports of serious declines in public confidence and appreciation of science over the past two decades, this attitudinal factor could be a critical influence on the future of both science and science education in the United States. An extensive review of the literature published over the past two decades revealed considerable research on several aspects of the problem, but little on this attitudinal dimension.

Purpose of the Study

The purpose of this study was to generate ideas about ways that science teachers might help students recognize and unlearn erroneous notions about science and replace them with sound new science concepts without lessening students' intellectual self-confidence or alienating their receptivity to further science learning.

The Research Methodology

Philosophical research methods are uniquely appropriate for initial enquiry into broad problems of this nature to generate new ideas and/or to illuminate additional options that may be compatible with the basic purposes and ideals of an institution, agency, or group. On this basis, speculative philosophical methodology was employed for this study.

Although philosophical enquiry is a common form of research, as indicated by its inclusion in the calls for proposals circulated by NARST, it is not typical of the empirical or quasi-empirical methods that characterize most educational studies. Unfortunately, it is not listed as a research or evaluation methodology in many major educational references, and it receives only cursory mention in others such as Worthen and Sanders (1973). Consequently, its unique and essential qualities are unfamiliar to many educators, and it is often confused with other forms of enquiry such as historical, naturalistic, futuristic, and correlational research. For this reason, a brief explication of the nature and applications of philosophical enquiry is appended to this study for the convenience of those who may be unfamiliar with that form of research (See Appendix 1).

The Procedure for the Study

There are three major types of philosophical activity: normative enquiry; analytical investigation, which is sometimes called "critical analysis"; and speculative, or "synthetic," philosophy. Normative studies have as their end the justification of value judgements about what individuals, societies, and/or sociocultural institutions may aspire to do; consequently, ethical and/or aesthetic questions constitute the predominant focus of this category of philosophical research.

Analytical and speculative studies aim to extend the limits of present human knowledge. Analytical research, which constitutes the majority of contemporary philosophical activity, functions to analyze and clarify the assumptions and concepts upon which a field of inquiry bases its conclusions. Speculative enquiry, on the other hand, seeks to expand the boundaries of present knowledge by synthesizing the conclusions of a field or fields and then filling in the gaps with speculation, or reasoned conjecture. Synthetic, "speculative" procedures were employed for this study to facilitate as open an assessment of the issue as possible.

Speculative philosophical examination of the problem of the unlearning of incorrect science concepts was conducted in four phases:

1. Clarification of the issue through a review of literature on the problem of common misconceptions of science. The review of literature encompassed more than 80 publications in the fields of science education, educational psychology, the physical sciences, and the history and philosophy of science.

2. Reflective analysis of the nature of the common misconceptions of science revealed in the literature, and synthesis of pertinent points of view regarding the implications of that information for science education.

3. Speculative assessment of the major studies for insight and ideas regarding alternative ways that the problem may be approached with sensitivity to both the nature of science and the nature and source of student preconceptions.

4. Speculative justification of conclusions from phase three, and suggestions for further research.

Observations from the Study

The review of literature revealed reports of studies on the problem of alternative conceptual frameworks related to virtually every science-related field and spanning the full spectrum of education from kindergarten through college. For example, Za'rour (1976), in a study involving 220 Lebanese Arab students ranging from kindergarten to fourth grade, reported many common misperceptions in the area of chemistry, physics, earth science and biology. Ault (1984), DiSessa (1982), Driver (1983), and Eaton et al. (1983) observed naive preconceptions among elementary and middle-school students on a diversity of topics including astronomical phenomena, biological growth and adaptation, molecular theory, composition of air and atmospheric pressure, energy, electromagnetic theory, time and space, gravity, and the relation of force and motion. Kuethe (1963), McCloskey (1983), and Viennot (1979) reported similar problems among hundreds of high-school seniors and

college students, especially with regard to concepts of force and motion, thermodynamics, and astronomy.

From a review of studies involving students from Canada, Germany, Israel, Lebanon, Norway, Scotland, Sweden and the United States, Driver(1983) concluded that "the general picture that emerges is of a considerable number of secordary pupils holding on to certain intuitive notions despite the science training they receive in school" (p. 30). Other research on the retention of naive preconceptions of science, such as the medieval concept of impetus, among college students supports Driver's conjecture. For example, McCloskey (1983) reported that "although Newton's Laws are well known . . . many people believe that moving objects behave otherwise" (p. 122). Clement (1982), reporting on a study of freshmen engineering majors prior to their introductory college physics course (most had studied high-school physics), noted that the majority (88 percent in one case) of students attempted to explain acceleration in non-Newtonian terms.

Many earlier studies of the problem of incorrect preconceptions in science focused on the cataloging of common misconceptions. These studies have helped to point out the problem areas, Driver concluded, but some have also given the impression that the sources of erroneous perceptions are simply mislearned facts. Obviously, she conceded, some erroneous preconceptions may be of this nature, and these could be easily corrected by the teaching

of new, correct facts. However, she argued, there is a preponderance of evidence that the problem is not nearly so trivial nor its solution so superficial: "In many cases the source of particular errors derives from pupils having very different models or alternate frameworks from those of the scientific community" (Driver, 1983, p. 26). These alternative frameworks, she contended, cannot be disregarded in science education. McCloskey (1984) concurred on the basis that many students who hold incorrect alternative concepts appear to interpret new course materials within that erroneous framework.

DiSessa concluded that it is unrealistic to assume that erroneous concepts will disappear and be replaced by correct information in the routine course of science instruction. About 50 percent of students, even at the university level, approach problems of force and motion from a non-Newtonian perspective very similar to Aristotelian physics, she found; and in most cases this outdated frame of reference appeared to provide fully satisfactory explanations of numerous experiences during their lifetimes. McClosky (1984) cited a widespread occurrance of outdated medieval notions of science that "persist today, perhaps because they seem to explain, simply, much of what we observe about motion in everyday life" (p. 55). Eaton et al. (1983) reported deep-seated misperceptions of the nature of light that prevented many students from learning its correct role in photosynthesis: "Most students never made the connection

between light and food making; they had explained the phenomenon to their own satisfaction without it" (p. 8).

Clement (1982), whose research revealed a prevalence of pre-Newtonian concepts of motion among three groups of college science majors, observed that some incorrect notions "appear to originate in intuitive preconceptions that the student develops on his own before entering courses" (p. 66). Driver cited evidence that children at a very early age construct such preconceptions, formulated as sets of expectations about natural phenomena, in an effort to make sense of everyday experiences. McCloskey (1984) cited similar evidence of quite sophisticated conceptual frameworks that four-year olds developed to explain their observations of objects in motion. Ault (1984) reported similarly conceived misperceptions of the nature of both time and mathematics among groups of first-grade students. Consequently, as Clement observed, teachers cannot assume a student's mind to be a "blank slate" in the area of science prior to their first science instruction.

As indicated earlier, several studies reported that many well-educated adults have retained erroneous intuitive notions about objects in motion despite formal study in high school and college science. Clement reported that, even after two semesters of college physics, 70 percent of the subjects in one test group of engineering majors still attempted to explain the mechanics of a coin-toss in terms of a "'motion implies force' belief" (Clement, 1982, p. 69).

Furthermore, Boyd (1966) reported no direct relationship between the number of science courses taken and the ability to correctly identify unfounded beliefs about science. Certain deep-seated, erroneous perceptions of natural phenomena, especially those that have provided satisfactory explanations of student observations over long periods of time, are "not likely to disappear simply because students have been exposed to the standard view in the [science] courses" (Clement, 1982, p. 70).

The research also indicated that basic errors regarding the nature of force and motion are among the most prevalent and persistent misconceptions encountered (Clement, 1982; Diressa, 1982; McCloskey and Kohl, 1983). Considering the fundamental role of Newtonian physics in all aspects of modern science, this bespeaks a critical situation for science education. Although additional research is needed to establish the full educational import of this issue, it is clear that erroneous preconceptions of science, especially those relating to the basic elements of Newtonian physics, constitute a critical challenge to science education for many, perhaps the majority of, students.

Research has also indicated that successful science education will require more than an opportunity for students to refute their misperceptions through exposure to superior scientific concepts in the course of their science studies. A synthesis of the concerns of Clement, Diressa, Driver, McCloskey, and others further indicates that successful

science education will require new teaching strategies. Such strategies should ensure that basic misperceptions are recognized and their inadequacies realized, and that they are unlearned and replaced by superior concepts that are compatible with the principles of modern science.

Several writers made suggestions regarding teaching strategies. One group recommended that science teachers work together to develop discussion and questioning techniques that would identify student misperceptions and that they select curricular materials that "explicitly contrast these misconceptions with scientific explanations" (Eaton et al., 1983, p. 8). Once a misperception has been identified, they added, teachers should contrast it to the "correct" concept to show how and why the latter is superior and then provide instruction on the appropriate alternative through conventional science instruction.

Driver suggested a similar approach and recommended Harvard Project Physics (1970, Holt and Rinehart) as a curricular resource. She also strongly recommended the identification and correction of naive conceptual frameworks in the earliest stages of science education to minimize the residual effect of erroneous preconceptions on the interpretation of subsequent observations.

Clement declared that teachers should develop strategies that would "encourage students to articulate and become conscious of their own preconceptions by making predictions based on them" (Clement, 1982, p. 70). Teachers

should then encourage students to make explicit comparisons of the predictive efficacy of their preconceptions with that of accepted scientific explanations, based on empirical observations. Many students may retain very stable alternative views of key natural relationships, or "conceptual primitives," that underlie the basic principles of science such as Newton's laws of motion, he explained. For example, Newton's first law prescribes that a body in motion tends to remain in constant, straight-line motion unless acted upon by a resultant force; but Clement's study revealed that a majority of the subjects tested (all were engineering majors) "were applying the idea that continuing motion implies the presence of a continuing force" (Clement, 1982, p. 67).

Such erroneous preconceptions are so intuitively attractive and convincing, Clement (1982) indicated, that, when the correct concepts are encountered in the classroom or laboratory, they are commonly misperceived or distorted to fit the preconception. "In such cases learning becomes a process in which new concepts must displace or be remolded from stable concepts that the student has constructed over many years" (p. 66). The first step in that process, he declared, is helping students articulate their preconceptions so they may become <u>conscious</u> of the inadequacies of any misconceptions they may hold. Then, he implied, the correct alternatives, when presented through conventional instructional means, may be perceived as meaningful new

concepts to be learned rather than as confusing and/or irrelevant ideas that appear to conflict with student's observations of the world around them. Arons (1977) had advocated a similar teaching strategy to help students develop their thinking and reasoning processes.

DiSessa (1982) described a set of computerized laboratory exercises designed to help students recognize and unlearn erroneous preconceptions of force and motion and obtain an operational understanding of Newton's laws. Like Clement, she believed that an understanding of students' preconceptions about science may be critical to the success of the teaching effort. Otherwise, some of the more entrenched preconceptions may outweigh "the perturbations we can apply as teachers" (p. 65). Like Disessa, Driver (1983) argued that science teaching must begin at the level of students' preconceptions:

> It is important . . . to consider and understand children's own ideas as it is to give a clear presentation of the conventional scientific theories. After all, if a visitor phones you up explaining he has got lost on the way to your home, your first reaction would probably be to ask "Where are you now?" You cannot start to give sensible directions without knowing where your visitor is starting from. Similarly, in teaching science it is important . . . to take into acccount both children's own ideas and those of the scientific community.
>
> (Driver, 1983, p. 3)

Driver attributed much of science education's failure to dispel naive preconceptions to "The Fallacy of Inductive Science Teaching" (Driver, 1983, p. 1). By the time children reach txeir first science class, they already have

many well-developed, albeit often naive, conceptual frameworks with which they interpret natural phenomena. Consequently, interpretations of the same data may vary greatly among students, depending upon the preconceptions they bring into the laboratory. This possibility of multiple interpretations of data, she concluded, constitutes a serious problem in inductive science teaching:

> On the one hand, pupils are expected to explore a phenomenon for themselves, collect data and make inferences based on it; on the other hand, this process is intended to lead to the currently accepted scientific law or principle.
> (Driver, 1983, p. 3)

Many of the principles of modern science do not spring clearly from data, Driver argued. Relationships that are immediately obvious to a trained scientist may be quite obscure to students in a laboratory class. Therefore, teachers cannot depend upon the theoretical models and conventions of science being "discovered" in the course of practical experiences--many are simply not that obvious. Guidance may be necessary for many students to make the conceptual leap required to comprehend their experiences in terms of conventional scientific principles; otherwise, their exposure to the "correct" concepts may either confuse them or inadvertantly reinforce an erroneous preconception.

> Not only do children have to comprehend the new model or principle being presented to them, but they have to make the intellectual leap of possibly abandoning an alternative framework which until that time had worked well for them.
> (Driver, 1983, p. 9)

Further discussion of Driver's constructivist position is beyond the scope of this report, but the following general comments are germane. The philosophical basis of her point of view was established on the revolutionary science historiography of Kuhn (1970) and others who advocated the increasingly popular paradigmatic concept of scientific development. Driver's position was also convincingly grounded in the psychological concepts of two major educational theories: Piaget's theory of cognition and Ausubel's theory of meaningful learning. Also, Driver's work constituted the most comprehensive treatment of the educational implications of naive science concepts that was encountered in an extensive search of literature on the subject. Driver's ideas, several of which would be considered controversial in some science education circles, are worthy of careful consideration by all concerned with the future directions of science education.

McCloskey reflected a widespread belief that the study of the common misperceptions of science "and the processes by which they are acquired and modified holds promise for the development of improved educational methods" (McCloskey, 1983, p. 130). The nature and origins of scientific knowledge per se have been the center of intensive research among educational philosophers and psychologists for generations. However, the nature and origins of commonly held naive preconceptions of science represent a new field

of educational inquiry that is presently in the speculative stages of early development.

McCloskey, like Driver, speculated that the more prevalent misconceptions of science are the product of intelligent efforts to make sense of day to day observations of natural phenomena. For example, McCloskey (1983) explained, when a child gives a ball a push and it continues to roll across the floor, the child may intuitively conclude, by quite logical reasoning processes, that the ball continues to roll because an internal or external causal force was somehow imparted to the object by the pusher--a reasonable but erroneous conclusion that may be reinforced by repeated observations.

McCloskey, Washburn, and Felch (1983) attributed certain misconceptions to perceptual illusions. For instance, they explained, objects dropped from moving carriers are frequently perceived as falling straight down because of the moving frame of reference. McCloskey (1984) cited examples of situations in movies and cartoons (usually for purposes of comedy, of course, as with the coyote's falls from the inevitable cliffs in the Road Runner series) that depicted some of the prevalent misperceptions of objects in motion.

"Seeing is believing" is a common and not unreasonable reaction among most inquisitive observers, McCloskey, Washburn, and Felch (1983) hypothesized; and misperceptions of this nature may become the basis of an erroneous but

deeply entrenched framework of reference by which future encounters with objects in motion are mediated. "Many people seem to get along pretty well despite their mistaken intuitions about motion," (McCloskey, 1984, p. 58). Such errors "appear not to be simply capricious; the belief appears to be plausible theory that has been constructed by students on the basis of experience" (Clement, 1982, p. 69). Such beliefs, then, are not unreasonable--and they are certainly not "dumb" or "stupid." Rather, they may be intelligently conceived and quite reasonable, but naive--unsophisticated, having never met with sufficient challenge from worldly experience to necessitate their serious reconsideration.

So long as the consequences of scientific misperceptions are not critical, the problem of erroneous science knowledge may not appear to be a serious problem to the naive believer. Research has clearly indicated, however, that some commonly-held erroneous notions of science represent a potentially serious impediment to additional science education, which can be a serious problem in a science-oriented society. Furthermore, McCloskey (1984) contended, some naive concepts may represent a potential hazard to personal safety: "The laws of physics can come into play at any time, possibly transforming our intuitive beliefs from amusing foibles into dangerous ignorance" (p. 58). In either case, the developing of teaching strategies designed to help students identify and correct erroneous

preconceptions of science should be an immediate priority in science education.

Speculation and Recommendations

Philosophical examination of the referenced studies and commentaries on the subject of common misperceptions of science justified several basic assumptions upon which subsequent speculation was based regarding ways science teachers might help students unlearn erroneous notions about science. The initial assumption was that erroneous preconceptions of many fundamental concepts of science are held by a major portion of society. This was clearly justified on the basis of evidence cited by several researchers. (This assumption could probably also be justified on the basis of several national studies on the level of scientific literacy.) The literature also provided clear support for assuming that certain intuitive misconceptions constitute a threat to subsequent science learning in related conceptual areas.

A third assumption, which derives logically from the second, was that teachers cannot depend upon subsequent exposure to conventional science instruction to displace the more prevalent and deep-seated misconceptions. Clement's and McCloskey's research, and several studies cited by Driver, also tendered empirical support for this assumption.

A fourth assumption, that new or revised teaching strategies would be necessary to help students articulate,

unlearn, and replace naive preconceptions, was likewise subsumed from the recommendations of several studies. A fifth enabling assumption, that such strategies can be developed, was accepted a priori for purposes of further study of the issue.

Synthesis and analysis of the major conclusions and recommendations gleaned from the referenced studies revealed an apparent similarity of some of the common misconceptions of science encountered today and certain outdated ideas that were once accepted as "good science" by scientific thinkers in the past. Ault (1984), for instance, found that many students hold an erroneous notion of time that generally resembles the outdated Newtonian concept of absolute time. Viennot (1979) found a common tendency to identify force with velocity, a notion that is contrary to Newtonian mechanics but an integral component of Aristotelian physics.

DiSessa (1982) found among students a widespread tendency to employ common-sense preconceptions characteristic of the antiquated Aristotelian system of physics when dealing with certain problems related to projectile motion--such as explaining how to kick a moving soccer ball toward a goal. Clement (1982) and McCloskey (1983, 1984) reported research indicating that many people, science students included, attempt to explain falling objects and projectile motion in terms remarkably similar to the intuitive, medieval concept of impetus. Because of the prominent mention of the impetus theory in this report, a

brief discussion of the theory by McCloskey (1983) is appended to this report (see Appendix 2). Further information regarding this concept, which constituted the theoretical basis of physical science during the three centuries preceding Newton, may be found in major works on the history of science, including Toulmin and Goodfield (1961).

Interestingly, Aristotle's common-sense concept of projectile motion, which prevailed for about 1500 years for lack of a better explanation, was finally discarded as inadequate and replaced by the intuitive medieval concept of impetus in the late Middle Ages. The impetus theory was in turn rejected as inadequate and was replaced by Newton's theories in the seventeenth century. Consequently, many of the common misconceptions of the behavior of objects in motion cited among modern students were found to be very similar to an intutive concept that was accepted for several centuries as the basis of science by leading scientific thinkers of that era. This, and Driver's contention that many of the naive concepts held by today's students appear to be intuitively-derived conceptual frameworks, prompted speculation that additional similarities may be found between the common misperceptions of science and the outdated principles of ancient, medieval, or early modern scientific thought.

A survey of the history of science quickly revealed examples of once accepted scientific concepts similar to

several of the common misconceptions identified in the studies of Driver, McCloskey, Za'rour and others. Students may therefore find parallels to many of their own intuitive misconceptions of science in the ideas of great scientific thinkers of the past--assuming that students are exposed to the history of science. For example, many persons holding erroneous preconceptions of the behavior of objects in motion may find portions, if not all, of their own ideas reflected in the theories held by earlier scientific thinkers such as Aristotle, Leonardo da Vinci, Copernicus, and/or Galileo. Students having trouble with the concept of relative time may find their views championed by John Locke, for instance, in his defense of Newton's concept of absolute time. Likewise, those students may find their understanding of time--and science--enhanced by examining the reasons that Liebniz, Einstein and others gave for rejecting Newton's ideas of time and adopting a different concept.

Implicit in those observations and a comment by Ault is a possible key to the problem of how students may be helped to recognize and replace erroneous science concepts in a way that will simultaneously preserve their intellectual self-confidence and receptivity to further science learning. Discussing problems that children encounter in trying to understand the concept of time, Ault (1984) observed that, "in this struggle to grasp the unobvious, children and great thinkers of the past find kinship" (p. 22). In another context, a student holding erroneous intuitive concepts of

motion similar to the antiquated theory of impetus may sense an intellectual kinship with Galileo (who endorsed the impetus theory for a time, but abandoned it in his later years), or da Vinci, or Oresme, or Kepler, to name a few scientific luminaries who held similar, intuitively justified ideas to be sound scientific fact.

It is reasonable to speculate that the systematic inclusion of the history of science, specifically the history of the development of those major conceptual areas about which common misperceptions exist today, could help students recognize the inadequacies of their own incorrect ideas and simultaneously gain an appreciation of the nature and worth of science. Learning that some of their own ideas were once held to be correct by outstanding scientists should help students maintain their intellectual self-confidence as they are introduced to the findings of later scientists who found those once acceptable ideas inadequate, and why.

After all, in many cases cited by McCloskey, Clement, and DiSessa, students holding naive concepts of motion had developed their intuitive preconceptions through their own observational and intellectual prowess without formal instruction in science--and came up with ideas resembling a conceptual framework that was once held to be scientifically correct by the great scientists of the world. If, after reviewing the reasons subsequent scientific thinkers found it necessary to abandon those ideas, students also find

themselves able to understand (perhaps with an imaginative teacher's help) why another concept was adopted as superior, they should become quite aware and appreciative of two things: 1) the superiority of the new concept; and 2) their own ability to "think scientifically" and to benefit from further science study. In other words, they should find an intellectual kinship with an even bigger circle of accomplished scientific thinkers.

Accommodation of new science information in this manner should bolster rather than offend students' intellectual self-confidence and interest in science; consequently, this sort of learning experience should accomplish several very important goals of science education. For instance, it should produce new science learning through the correction of erroneous preconceptions, while simultaneously creating an acute awareness of the nature and purposes of the scientific enterprise. Attitudinally, it should create an awareness of the worth of science study while simultaneously enhancing students' self-confidence regarding their capacity for self-initiated scientific thinking. It should also help to demonstrate the tentative nature of scientific knowledge in a way students can clearly understand and appreciate.

Helping students achieve such learning experiences may be approached in a few steps, two of which have already been suggested in the referenced literature. First, of course, would be the development and deployment of teaching

strategies that would help students discover and articulate their preconceptions of science, thereby enabling teachers to assess students' current comprehension of that subject (Clement, 1982). Second, any incorrect preconceptions should be examined for possible similarities to once accepted but now outdated or otherwise inadequate scientific principles that may have existed during other periods in the history of science. Third, if a similarity can be established, a student should be encouraged to review the history of the concept to discover the strengths and weaknesses of his idea (and Aristotle's or Galileo's perhaps) and to critique the challenges of other scientific thinkers and learn for her/himself the strengths and weaknesses of the alternate concepts. Obviously, in cases where no similarity with historical conceptualizations of science is found, this third step would be bypassed. Next, students should be encouraged, as Eaton et al. (1983) recommended, to conduct laboratory exercises comparing the predictive efficacy of their preconceptions with the conventional science concepts, thereby learning for themselves the superiority of the new ideas.

In Piagetian terms, learning occurs, within the limits of cognitive development, as new cognitive structures are formed by the assimulation of new information sufficient to resolve disequilibrium resulting from conflict between environmental observations and individual expectations. If the dissonance created by novel experiences is either too

little to motivate assimilation or too great to accommodate through cognitive restructure, learning will not occur. Ausubel, on the other hand, contended that learning occurs only when the new information is sufficiently meaningful to be relevant to what the learner already knows or wants to know.

Ideally, the use of the history of science in the manner indicated above would create an intellectual disequilibrium among students holding erroneous preconceptions by helping them to realize the inadequacies of the concepts they had, until then, considered fully adequate. The procedure would also expose the individual to alternative information in a systematic manner that, again ideally, would aid in the cognitive restructure necessary to unlearn (discard the habit of) the old concept and replace it with an acceptable new conceptual framework. Driver cautioned that, even if its inadequacy is recognized, an erroneous preconception is not likely to be replaced in a student's mind unless a satisfactory alternate concept is available to replace it. Kuhn (1970) concluded that a similar situation prevails in the scientific community, which discards inadequate research traditions only in the presence of a new paradigm that appears to be superior. Consequently, the careful integration of the demonstrably superior concepts of modern science into the type of learning experience described above should culminate in successful science education. From the Ausubelian

perspective, once a student is confident of the superiority of the new concept, the examination of other preconceptions in like manner may be perceived as meaningful learning activities to be pursued.

Obviously, as conceded earlier, there may be many misconceptions for which parallels are not readily found in the history of science. However, the research of Clement, DiSessa, Driver, and McCloskey indicated a prevalence of common misconceptions of the behavior of objects in motion that clearly resemble the intuitive conceptual frameworks of motion that prevailed during the pre-Newtonian era of science. Consequently, this one conceptual area alone could constitute the basis for a meaningful introduction, or reintroduction, of Newtonian physics to a major portion of any given class.

Given the prevalent nature of common misconceptions concerning other basic areas of science that have undergone significant changes in the history of science, it is likely that many students may hold several naive concepts that could be illuminated by a review of the developments of their counterparts in the history of science. Consequently, practitioners of the instructional strategy discussed above should find ample opportunity for its use. On that basis, the following recommendations for research and/or development in science education are presented.

An immediate priority should be the development of reliable diagnostic tests designed to identify and classify

as many common misperceptions of science as possible. Ideally, such tests should require no advanced mathematical skills or formal science training and should be applicable to the testing of out-of-school adults as well as school and college students. Clement (1982) presented examples of simple but effective questions of this nature which were used for testing college students' understanding of Newtonian mechanics.

A second priority should be the development of teaching strategies designed to help all classroom students articulate their preconceptions of science, correct or otherwise, as well as how they process information with those preconceptions. Though several researchers mentioned the need for this sort of strategy, none were specific regarding the sort of instructional methods that would be required.

Once the basic classifications of common misperceptions of science are determined, the history of science should be searched for as many historically significant similarities as possible. Several science educators, including Conant (1951) and Klopfer (1969) have advocated the use of case histories of the evolutionary or revolutionary development of the major concepts of science to help students understand the purposes and processes of science. The works of these educators and their colleagues should be carefully examined for ideas regarding the possible application of already existing case histories. It is likely that a single case

history would encompass several classes of common misconceptions.

Finally, a series of simple laboratory exercises adapted to each of the major classifications of misconceptions would be required to help students make predictions and conduct experiments to test the explanatory efficacy of those preconceptions. In many cases, parallel exercises based on the conventional alternatives to each major class of misconceptions could be adapted from existing curricular resources.

With this approach, students would have the opportunity to learn both the basic principles of modern science and the advantages of those concepts over their alternative ideas. They would be provided learning experiences that would help them make the conceptual leap from whatever naive, intuitive preconceptions they brought into the classroom to the conventional scientific principles they need to know for further science learning and for the correct interpretation of their natural environment. Students should also be more receptive to further science instruction than might be expected with conventional instructional strategies that simply present modern science concepts with little or no regard for their prior interests and/or conceptual frameworks.

Conclusions

In conclusion, the selective employment of historical counterparts of the common misperceptions of science should help students recognize the inadequacy of their own misperceptions and replace them with more satisfactory alternatives. Students would more likely retain their intellectual self-confidence and gain a clearer understanding of the nature and worth of modern science. Many students likely would be motivated to further study as a basis for examining their other ideas about science. Science teachers using such a teaching strategy may therefore achieve several of the major objectives of science education, both cognitive and affective. These conclusions provide sufficient philosophical justification for a recommendation of further research to assess the effectiveness of the teaching of the history of science for helping students unlearn specific misconceptions and replace them with acceptable alternative frameworks.

Finally, erroneous preconceptions of science may have persisted throughout the formal science training of some science education majors, as was the case with Clement's engineering majors. Immediate attention should be given to developing procedures to aid teachers in assessing their own science backgrounds for possible misconceptions that may impact upon their teaching. Furthermore, it is strongly recommended that formal study of the history of science, consisting of a comprehensive study of the development of

ancient, medieval, and modern science, become an integral component of science teacher training.

REFERENCES

Arons, A. (1977). The Various Language: An Inquiry Approach to the Physical Sciences. New York: Oxford University Press.

Ault, C. R., Jr. (1984). Intelligently wrong: Some comments on children's misconceptions. Science and Children, 1984, 21(8), 22-24.

Boyd, C. A. (1966). A study of unfounded beliefs. Science Education, 50(4), 396-398.

Caramazza, A., McCloskey, M. & Greene, B. (1981). Naive beliefs in "sophisticated" subjects: Misconceptions about trajectories of objects. Cognition, 9, 117-123.

Carleton, R. (1961). Editorial. The Science Teacher, 28(7), 4.

Champagne, A. B., Klopfer, L., & Anderson, J. (1980). Factors influencing the learning of classical mechanisms. American Journal of Physics, 48, 1074-1079.

Clement, J. (1982). Students' preconceptions in introductory mechanics. American Journal of Physics, 50(1), 66-71.

Conant, J. B. (1951). Science and Common Sense. New Haven, Connecticut: Yale University Press.

DiSessa, A. A. (1982). Unlearning Aristotelian physics: A study of knowledge-based learning. Cognitive Science, 6(1), 37-75.

Driver, R. (1983). The Pupil as Scientist ? Milton Keynes, England: The Open University Press.

Eaton, J., Anderson, C., & Smith, E. (1983). When students don't know they don't know. Science and Children, 20(7), 6-9.

Greene, J. C. (1959). The Death of Adam. Ames, Iowa: The Iowa State University Press.

Hirst, P. & Peters, R. (1970). The Logic of Education. London: Routledge and Keegan Paul, Ltd.

Hurd, P. D. (1982). Transformation of science education: Challenge and criteria. Science Education, 66(2), 281-285.

Klopfer, L. E. (1969). The teaching of science and the history of science. Journal of Research and Science Teaching, 6, 87-95.

Kuethe, J. L. (1963). Science concepts: A study of "sophisticated" errors. Science Education, 1963, 47(4), 361-364.

Kuhn, T. S. (1962). Historical structure of scientific discovery. Science, 136, 760-764.

Kuhn, T. S. (1970). The Structure of Scientific Revolutions (2nd Edition). Chicago: The University of Chicago Press. (Originally published, 1962).

McCloskey, M. (1983). Intuitive physics. Scientific American, 248(4), 122-130.

McCloskey, M. (1984). Cartoon physics. Psychology Today, 18(4), 52-58.

McCloskey, M. & Kohl, D. (1983). Naive physics: The curvilinear impetus principles and its role in interaction with moving objects. Journal of Experimental Psychology: Learning, Memory and Cognition, 9(1), 146-156.

McCloskey, M., Washburn, A., & Felch, L. (1983). Intuitive physics: The straight-down belief and its origin. Journal of Experimental Psychology: Learning, Memory, and Cognition, 9(4), 636-649.

Reid, C. L. (1971). Basic Philosophical Analysis. Encino, California: Dickenson Publishing Company, Inc.

Toulmin, S. & Goodfield, J. (1961). The Fabric of the Heavens: The Development of Astronomy and Dynamics. New York: Harper Torchbooks, Harper & Row, Publishers.

Toulmin, S. & Goodfield, J. (1962). The Architecture of Matter. Chicago: University of Chicago Press.

Toulmin, S. & Goodfield, J. (1965). The Discovery of Time. Chicago: University of Chicago Press.

Viennot, L. (1979). Spontaneous reasoning in elementary dynamics. European Journal of Science Education, 1, 205-221.

Worthen, B., & Sanders, J., Jr. (1973). Educational Evaluation: Theory and Practice. Belmont, Calif.: Wadsworth Publishing Company.

Za'rour, G. J. (1976). Interpretation of natural phenomena by Lebanese school children. Science Education, 60(2), 277-287.

APPENDIX 1
EXPLICATION OF PHILOSOPHICAL ENQUIRY

Philosophical research is unique in that it does not function within a discipline but rather functions to think about that discipline. It is not an appropriate method for solving problems in science education, or in history, or in science, or in religion, or in anything else. Each discipline has its own unique problem-solving traditions for that purpose. For example, empirical or quasi-empirical research methods are quite appropriate to determine if a particular goal or objective is practical and/or attainable within science education. Philosophical methods are essential, however, when an institution, agency, or group needs to take a detached look at, or think objectively about, what it is doing to see if its ideas and/or anticipated actions are reasonable and compatible with its basic purposes and ideals. In summary, philosophical enquiry about a profession's goals can illuminate those options that the group may reasonably consider, but which options to choose and what actions to take are decisions that must be made within that profession.

Theoretical parameters, hypothetical constructs, and/or too-explicit goals are generally contrary to the nature of philosphical research (many philosophers of science contend that such methodological constraints are also inappropriate for scientific research). The goals of enquiry must be general, the procedures open, and the field of enquiry unfettered by disciplinary bounds to allow maximum

opportunity for reflection, imagination, inspiration, and discovery; and the conclusions should be as general as possible. The research should begin, proceed, and conclude as much as possible without hindrance from prior supposition. For instance, "if you . . . insist that all things must have something in common, you have gone at it backwards: First, find that common trait, then talk about it" (Reid, 1971, p. 7).

Philosophy serves two unique and essential functions: the justification of fundamental standards, and the assessment of basic concepts. In 1961, the editor of The Science Teacher highlighted the hazards of attempting to establish science education needs or goals without clearly established standards upon which to justify such actions: "All of us are caught up in the 'pursuit of excellence,' but all too often, this sort of pursuit becomes a mad rush to "do something," even though we are not sure that it is right. . . . We seldom take the time to think and spell out what is meant by excellence" (Carleton, 1961, p. 4). A review of the history of science education over the past quarter-century from this perspective will shed much light on the problems of operating an enterprise with "only minimum attention to its philosophical underpinnings" (Hurd, 1982, p. 281).

Basic concepts, or ideas, are the intellectual tools of a profession; and philosophy is a systematic means of examining those tools and how they are used. It is a means

of stepping back, so to speak, to make a detached assessment of an enterprise with regard to its overall purposes and its relation to basic social values and cultural norms. Since philosophical evaluation is not an integral component of their day-to-day operations, many professionals are not accustomed to this sort of activity. However, this is not necessarily bad, one philosopher explained, so long as the need for such philosophical assessment is not ignored or forgotten:

> It is only natural and right that people should be more interested in using concepts than examining them. . . . The worker who spends all his time improving his tools never gets his work started. Usually there is no great need to examine basic assumptions and basic concepts, just as usually most tools function well. But occasionally in all work, whether it is manufacturing or thinking, something goes wrong with the tools, and work on the job has to stop and work on the tools begins. (Reid, 1971, p. 12)

Kuhn, a science historian, concluded that, in any enterprise, intellectual or otherwise, "the significance of crises is the indication they provide that an occasion for retooling has arrived" (Kuhn, 1970, p. 76). If there is a crisis in science education, as many educators claim, then it is a clear signal that a philosophical assessment of its basic ideas and concepts about science teaching is needed--to see if they are the right tools for the job and if they are being used well. Since philosophy does not function <u>in</u> a discipline, it is not necessary to stop or interrupt the teaching enterprise to seek justifiable options for change. Once the options are philosophically

justified, the educational community may then select the most promising options and test them, hopefully with minimum risk, and apply them as indicated.

Philosophical enquiry, like any methodology, has strict limitations. It does not function to advocate action, to cause change, or to predict, or prophesy, or necessarily to modify the world. It functions to help put problems in the proper perspective so that it will be easier to understand "what reasons are good reasons for changing [things] or keeping things as they are" (Hirst and Peters, 1970, p. 131). It is a means of exploring for basic ideas or options and justifying their consideration prior to the conclusive commitment of irretrievable time and/or resources to a specific course of action.

APPENDIX 2

DISCUSSION OF THE THEORY OF IMPETUS

(Quoted from McCloskey, 1983)

The impetus theory was a medieval correction of Aristotle's account of motion; it was discussed by the Greek scholar John Philoponus in the sixth century and was developed most fully by the French philosopher Jean Buridan and others in the 14th century. A succinct statement of the theory was given by Buridan (in translation): "When a mover sets a body in motion, he implants into it a certain impetus, that is, a certain force enabling the body to move in the direction in which the mover starts it, be it upward, downward, sideward or in a circle. It is because of this impetus that a stone moves on after the thrower has ceased moving it."

The medieval impetus theory shared with Aristotelian physics the idea that motion must have a cause. The continuous action of a force was thought to be necessary to keep an object in motion, a concept Newtonian mechanics explicitly denies. In Aristotelian physics the force responsible for the motion was necessarily external to the moving object. This requirement made it quite difficult to explain the motion of a projectile, because once a projectile leaves its launcher it is hard to find any source of external force. In the impetus theory the difficulty was circumvented by assuming that the motion of a projectile is

maintained by force internal to the object, which is acquired when the object is set in motion. The internal force was called impetus.

To account for the observation that most moving objects eventually come to a stop impetus theorists also assumed that impetus gradually dissipates. For example, according to the impetus theory, a ball rolling across a floor gradually comes to rest because the impetus acquired when it was set in motion steadily diminishes until it is entirely exhausted. Some impetus theorists held that impetus dissipates spontaneously, whereas others, including Buridan, argued that external influences such as air resistance are responsible for its loss.

(McCloskey, 1983, p. 123)